Section 5. Pond Design Features And Requirements

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Appendix A: Hazard Classification Form

5.1. Applicability To DelDOT

This Section establishes the minimum acceptable stormwater management pond design standards for the Delaware Department of Transportation. These requirements were developed by combining design recommendations from many various publications and practical experience. Applicability of these standards are subject to the following limitations:

* The Hazard Classification conforms to class "a";
* The product of the pond storage volume times the effective height of the dam is less than 3,000. The storage is measured in acre-feet below the crest of the emergency spillway. The effective height of the dam is taken as the difference in elevation, in feet, between the emergency spillway crest and the lowest point in the cross section taken along the centerline of the dam.
* The effective height of the dam is less than 35 ft.

All submissions are to be based on these requirements, the most recent revisions of the Delaware Sediment and Stormwater Regulations (DSSR), and the USDA Natural Resources Conservation Service (NRCS) Small Pond Code 378, As Amended for Use in Delaware.

5.2. Stormwater Management Area

In determining a project's Right-of-Way requirements, the designer must delineate an area on the plans large enough to provide adequate access to each stormwater management pond during construction and for future maintenance activities.

The stormwater management area delineated on project plans shall include the pond itself plus a landscaping buffer. The landscaping buffer shall enclose the entire perimeter of the pond for a width of ten feet. The ten foot buffer shall be measured on the slope perpendicular to the contour lines. The measurement shall begin at the contour line corresponding to the peak water surface elevation in the pond during the 100 year storm event and proceed upgradient for a distance of ten feet.

As a minimum, the stormwater management area to be delineated on the plans shall include the following:

* The entire pond reservoir,
* The pond embankment to a point ten feet beyond the toe of the downstream slope;
* The principal spillway outlet channel from top of slope to top of slope plus ten feet on both sides to the end of the riprap apron or stilling basin,
* The emergency spillway channel in its entirety from top of slope to top of slope plus ten feet on both sides.

The figure below illustrates the main components of a stormwater management pond. All components pictured should be included in the stormwater management area delineated on the plans.

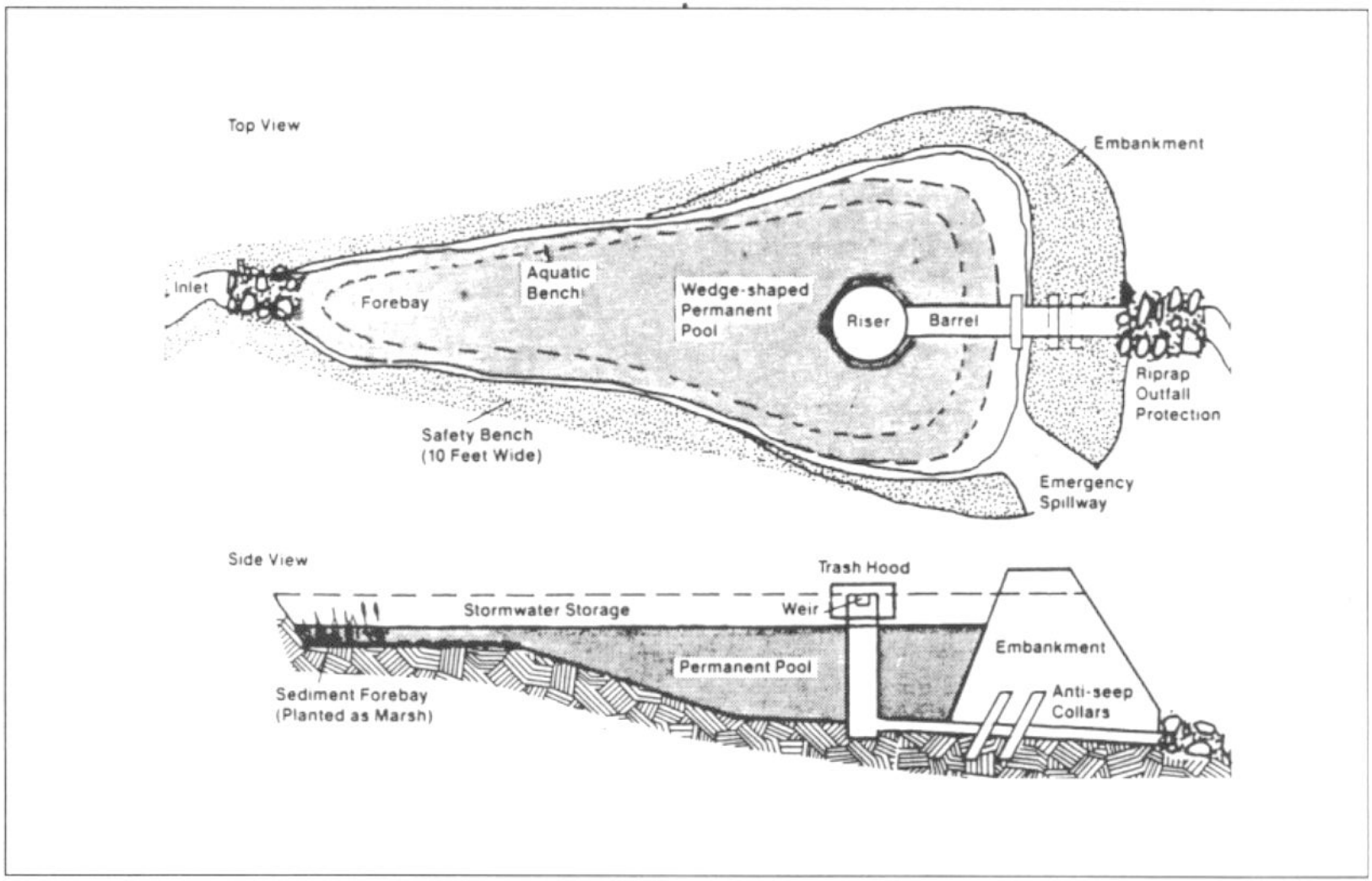
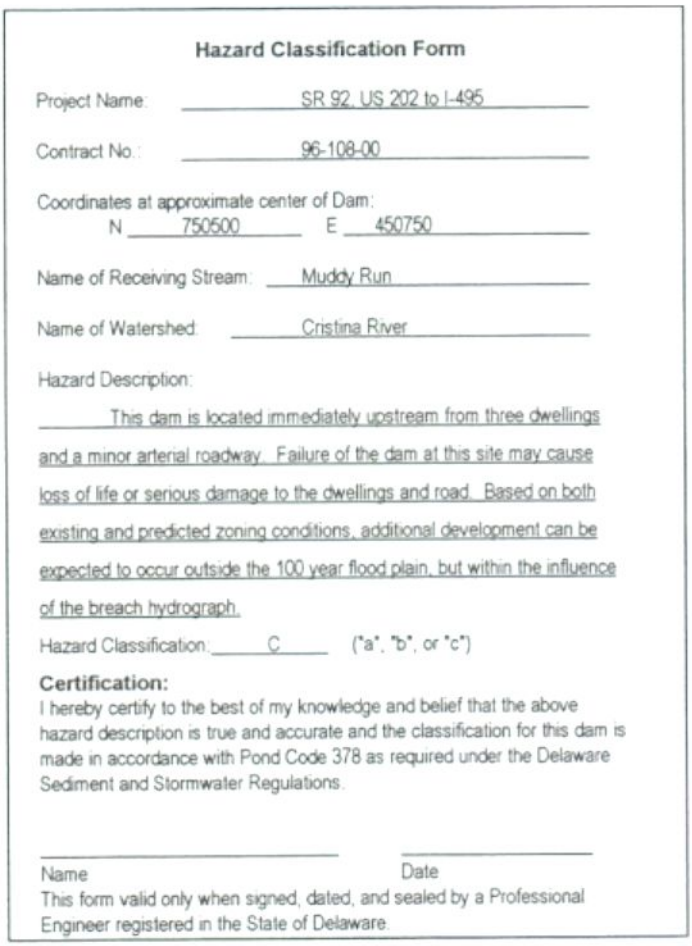


Figure 5.1.Schematic of a Wet Pond

5.3. Hazard Classification and Designer Certification

For embankment ponds, as defined in Pond Code 378, the hazard classification of a dam will determine the level of care and investigation necessary in the design of the pond and earth embankment.



Hazard Classification Form

Project Name: SR 92, US 202 to I-495

Contract No.: 96-108-00

Coordinates at approximate center of Dam:
N 750500 E 450750

Name of Receiving Stream: Muddy Run

Name of Watershed: Cristina River

Hazard Description:

This dam is located immediately upstream from three dwellings and a minor arterial roadway. Failure of the dam at this site may cause loss of life or serious damage to the dwellings and road. Based on both existing and predicted zoning conditions, additional development can be expected to occur outside the 100 year flood plain, but within the influence of the breach hydrograph.

Hazard Classification: C ("a", "b", or "c")

Certification:
I hereby certify to the best of my knowledge and belief that the above hazard description is true and accurate and the classification for this dam is made in accordance with Pond Code 378 as required under the Delaware Sediment and Stormwater Regulations.

Name Date

This form valid only when signed, dated, and sealed by a Professional Engineer registered in the State of Delaware.

The class ("a", "b", or "c") of the dam shall be based on the potential damage upstream and downstream of the pond that might result from a sudden major breach of the earth embankment.

Determination of the hazard classification shall take into consideration all future development in the watershed using the zoning in effect at the time of design.

Classification of a dam is the responsibility of the designer, and subject to review and approval from the Stormwater Engineer's office.

The designer of each embankment pond shall certify the hazard classification of the dam by completing, signing, and sealing the Hazard Classification Form. A sample of this form is shown at left. And a blank form is included at the end of the Section.

Figure 5.2. Hazard Classification Form

This form should be filled out and submitted with the stormwater management report for each project. To assign a hazard classification the designer should refer to the criteria given below:

Class "a" - Structures located in rural, agricultural, or urban areas dedicated to remain in flood tolerant usages where failure may damage non-resident buildings, agricultural land, floodplains, or county roads.

Class "b" - Structures located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads, or cause interruption of use or service of relatively important public utilities.

Class "c" - Structures located where failure may cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

Where breach analysis has indicated that overtopping of downstream roads will occur, the following guidelines will be used:

Table 5.1 Hazard Classification

Class	Depth of Flow (d) ft.
"a"	d is less than or equal to 1.0
"b"	d is greater than 1.0 but less than 3.0
"c"	d is greater than 3.0

Urban areas are defined as metropolitan areas, cities, and suburbs including areas in transition from agriculture to residential - industrial.

5.4. Minimum Pond Drainage Area

A. **Wet Ponds.** Wet ponds are not recommended for drainage areas less than four acres unless water from other sources is routed to the pond to augment surface runoff, maintaining a permanent pool. The designer shall submit a detailed water budget analysis when a wet pond is proposed for drainage areas less than four acres. As a minimum, this analysis shall take into account the site topography, soil seepage, evaporation rates, precipitation, surface runoff, flow augmentation, location of water table, seasonal changes, and stormwater reuse.

B. **Dry Ponds.** There is no specific minimum drainage area for a dry pond. However, there is a point at which the predicted flows to a dry pond become so small that the required outlet orifice sizes become the limiting factor in the design. Flows below a certain point result in extremely small outlet structures prone to clogging. When confronted with this situation, another stormwater management method should be considered. If because of topography, soils, and other site limitations, no other methods are available, then the 24 hour extended detention time requirement may be reduced rather than choosing excessively small outlets. (See Section 5.7 for recommended minimum outlet sizes).

5.5. Stormwater Quantity Control

A. **Allowable Discharges.**

1) **North of C & D Canal.** Projects located in the Peidmont region of the State (generally taken as areas in New Castle County north of the Chesapeake and

Delaware Canal) shall limit the post development discharges for the **2, 10,** and **100** year storm events to predevelopment levels.

2) **South of C & D Canal.** Projects in the Coastal Plain region of the State (generally taken as areas in New Castle County south of the Chesapeake and Delaware Canal, Kent County, and Sussex County) shall limit post development discharges for the **2** and **10** year storm events to predevelopment levels.

B. **Use of DelMarva Unit Hydrograph.** The DelMarva Unit Hydrograph should be used in determining peak rates of runoff in NRCS TR-55 and TR-20 hydrologic computations for projects located in the Coastal Plain areas of the State. This is generally described as areas below the Chesapeake and Delaware Canal. However, there are areas above the Canal which meet Coastal Plain characteristics and in some cases extend to Interstate 95.

5.6. Stormwater Quality Control

A. **Extended Detention.** All ponds, wet or dry, shall incorporate an extended detention component providing removal of at least 80 percent of suspended solids in accordance with the criteria set forth in Section 10-3-E(2) & (3) of the Delaware Sediment and Stormwater Regs.

1) **Wet Ponds.** The extended detention volume shall be provided over and above the permanent pool volume. The extended detention volume shall be computed by routing the storm which generates one half inch (1/2") of runoff through the pond. The routing must show a gradual release of the first one half inch (1/2") of runoff over twenty four (24) hours.

2) **Dry Ponds.** The extended detention volume shall be computed by routing the storm which generates one full inch (1") of runoff through the pond. The routing must show a gradual release of the first inch of runoff over twenty four (24) hours.

3) **Computation of Extended Detention Time**. The extended detention time shall be computed by subtracting the hydrograph time at which pond outflow begins from the hydrograph time at which pond outflow ends. For example, if outflow begins at 11.6 hours then it must continue at least up to 35.6 hours in order to verify a gradual release over 24 hours.

5.7. Safety, Maintenance, and Aesthetic Features

This subsection considers the various design aspects which effect the safety of stormwater ponds from the perspective of the general public as well as maintenance workers whose duty it is to clean, repair, and mow these facilities. Guidance is also provided in this subsection regarding design approaches which may optimize stormwater pond performance. And aesthetic design criteria are established to encourage designs which meet public expectations for attractive

naturally landscaped ponds. The Department's goal is to create ponds which will be considered an amenity to adjacent communities.

Designers should consider the following parameters regarding pond design

A. **Site Selection:**
- Locate the pond adjacent to the low spot in the roadway profile;
- Fit the pond to the original terrain;
- Design the pond to look like a natural part of the landscape;
- Locate the facility in a prominent area such that it becomes a known hazard.

B. **Dry Ponds vs. Wet Ponds.** Public perception is that dry ponds are safer than wet ponds. In actuality, it may be the opposite. With a wet pond, there is a permanent pool of water. Of course the water surface elevation may fluctuate slightly with the rain, but in general site conditions are fairly constant. The pond becomes a known hazard and people become accustomed to it. The pond will not tend to attract additional attention during a storm event.
However, a dry pond usually has no pool of water. It is only full for a short time during and after a storm. In between storms, these ponds tend to dry out and many are maintained as a manacured lawn. As a result, these facilities often become playgrounds. This may seem like an excellent secondary use of the facility, but this can be potentially dangerous. These areas change rapidly during a storm. Water depths may go from zero to several feet in less than an hour. Flow rates through the outlet works can be quite rapid and possess considerable force. The presence of the water may tend to attract the attention of children who are not accustomed to seeing the pond full and who may not understand the potential dangers of playing in the pond while it is functioning.
For these reasons and because the Delaware Sediment and Stormwater Regs prefer wet ponds, DelDOT recommends the use of wet ponds wherever feasible.

C. **Pond Grading.** A two stage design is recommended for both wet and dry extended detention ponds. The lower stage shall be sized to accommodate the extended detention volume. For dry ponds, the bottom of the lower stage should be graded to drain toward the principal spillway with a minimum slope of 100 feet horizontal to one foot vertical. It is recommended that the lower stage be managed as a meadow or shallow marsh as this zone is frequently saturated making regular mowing difficult. The upper stage shall consist of that zone located above the extended detention volume in a dry pond and above the permanent pool in a wet pond. The upper stage should be sized and graded to remain dry during interevent dry periods. The recommended slope is 10 horizontal to 1 vertical with an allowable range of 100:1 minimum and 3:1 maximum. A sample grading plan is shown below to illustrate these concepts.

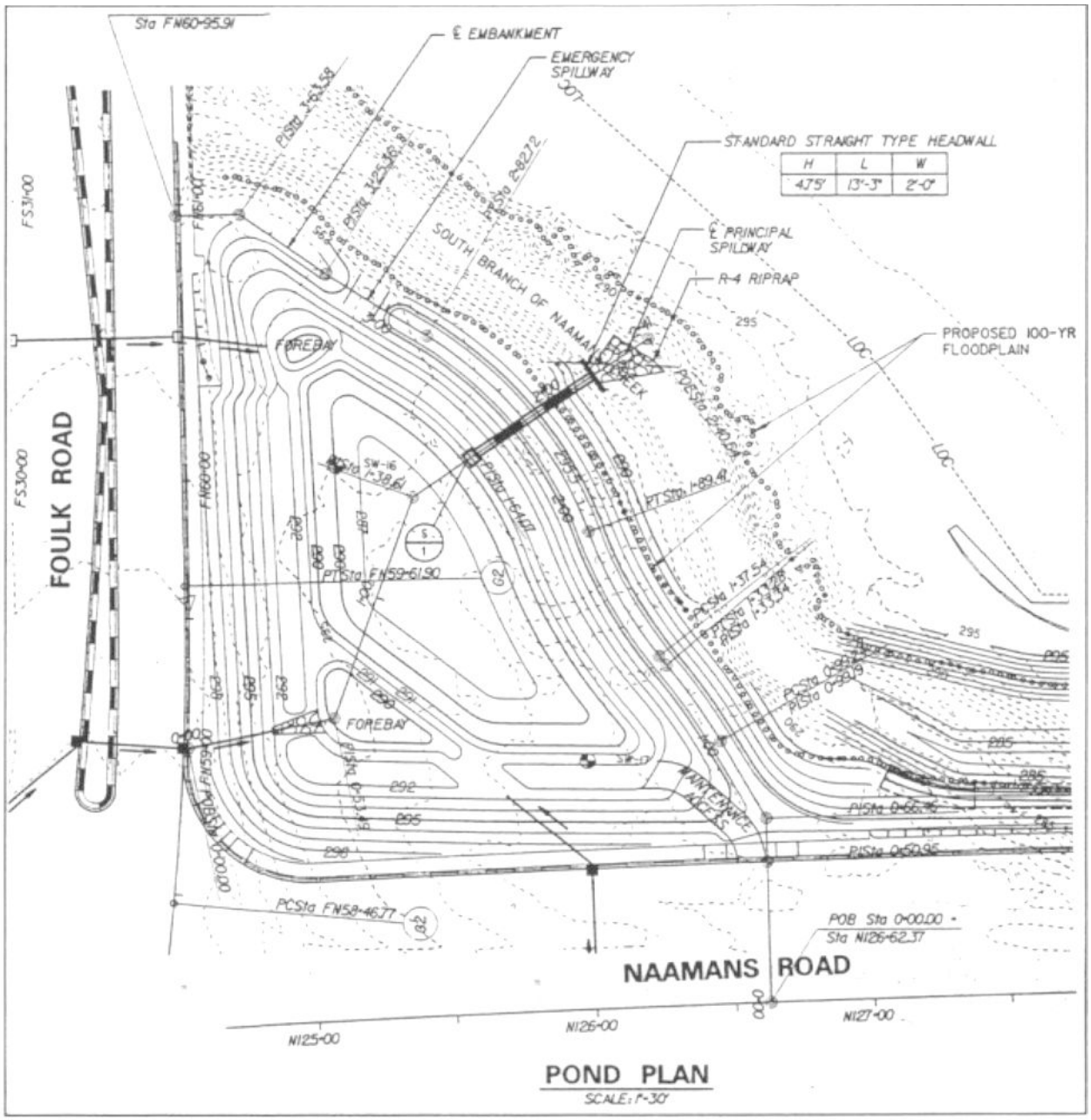


Figure 5.3. Sample Pond Grading Plan

D. **Pond Shape.** The perimeter of both the upper stage and the lower stage of a stormwater management pond shall follow an irregular curvilinear path. Geometric shapes such as squares, rectangles, and triangles shall be avoided.

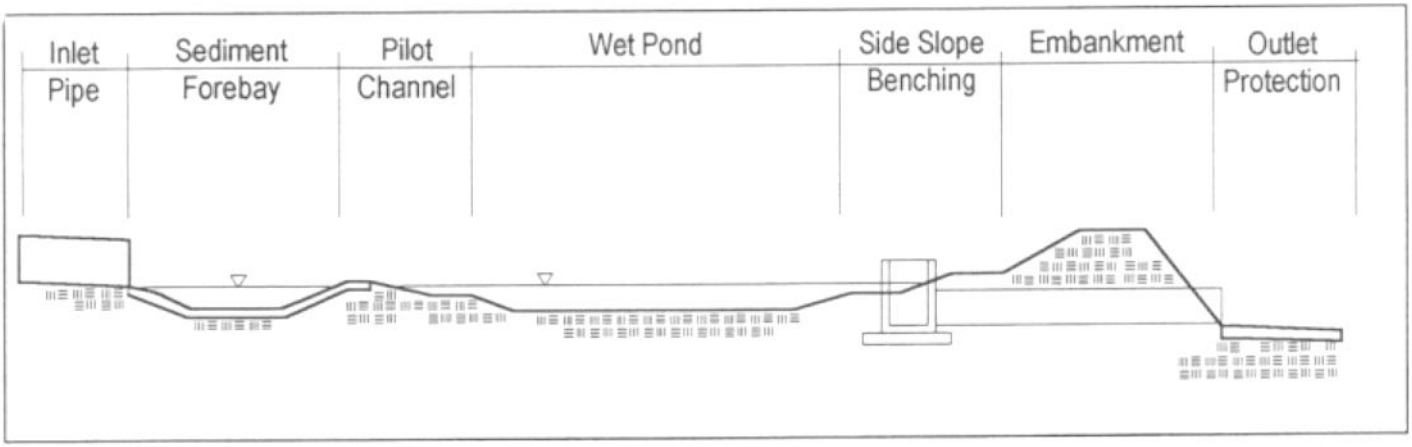


Figure 5.4. Typical Pond Cross Section

E. **Pond Side Slopes.** The flattest possible side slopes are recommended for optimal safety. Mowable slopes should be kept to a maximum steepness of 4 horizontal to 1 vertical. Under no circumstances shall the slopes be made any steeper than 3 horizontal to 1 vertical whether above or below the water surface of the normal pool.

F. **Side Slope Benching.** Ponds and temporary sediment basins having a permanent pool of water shall be designed to provide a 10 foot wide level bench one foot below the normal pool elevation for purposes of safety and establishment of emergent vegetation. A 10 foot wide reverse slope bench shall be provided one foot above the normal pool elevation for safety purposes.

G. **Pond Depth.** Pond depths should be kept within the following ranges:

1) **Dry Ponds.** Dry ponds shall not exceed a maximum water depth of four feet during the 100 year storm event.

2) **Wet Ponds.** Wet ponds may have normal pools up to six feet deep because they have the safety feature of a submerged bench about the perimeter. The maximum water depth during the 100 year storm event shall not rise more than four feet above the upper side slope bench.
From a maintenance standpoint, the optimal depth of the normal pool is in the range of 3 to 6 feet deep. The minimum depth to ensure an open pool of water and prevent resuspension of deposited material is 2 feet. The maximum depth to prevent thermal stratification and creation of anoxic conditions at the pond bottom is 8 feet.

H. **Location of Outlet Structure.** The outlet structure should be placed as far as possible from the inlet. A line connecting the inlet and outlet shall equal the longest dimension measured across the pond unless baffles or diversions are employed to increase the flow

length. The outlet structure should be located along the shoreline for ponds having a normal pool to facilitate maintenance access.

I. **Outlet Structure Accessibility.** Design of the pond outfall structure should consider the safety of those people who have to inspect and maintain it. Department personnel will need safe access to the inside of the structure. The design should also prevent unauthorized entry by others. Lockable hatches in the top of trash racks and manhole steps built in the side of concrete risers are recommended for these purposes.

J. **Fencing.** DelDOT does not encourage fencing around stormwater ponds for several reasons:

* When it comes to safety, fences are not a substitute for gentle pond banks and shallow depths;
* Fences may offer a false perception of safety, since most fences are easily climbed by even the smallest of children;
* DelDOT does not have the resources to maintain fences;
* Unmaintainted fences are a liability since lack of maintenance could be construed to allow or condone the unauthorized use of a facility;
* Fences can obstruct rescue efforts;
* The only fences DelDOT could afford to install are chainlink which are generally considered unaesthetic.

Fencing by itself is not considered an adequate means of providing a safe pond environment. No designs will be approved which propose to fence a pond in lieu of meeting the side slope and benching requirements outlined in this Section and Pond Code 378.

K. **Pilot Channel.** A low flow channel stabilized with a permanent vegetative lining system, such as turf reinforcement mat, should be used to route water from the upper stage to the lower stage in a two stage dry extended detention pond. The channel should end at the toe of slope of the upper stage where the lower stage begins. The outlet of the channel should be protected from scour by means of a rip rap apron, plunge pool, or other suitable energy dissipation device. Rigid linings, such as concrete and asphalt, are not recommended. Pilot channels should **not** be directly connected to the pond outlet structure.

L. **Forebay.** A forebay shall be provided at inlets to all stormwater management ponds to act as a permanent sediment trap. The forebay shall be designed as a plunge pool and may employ additional energy dissipation devices to prevent erosion and resuspension of deposited materials. In addition to the plunge pool volume, the forebay shall be sized to accept a volume of sediment accumulation from the project site after stabilization equal to the available set aside area for disposal of those sediments in accordance with Section 10.3.K.(1) of the DSSR.

The volume of the forebay should be considered a part of the overall flood storage volume required in the pond. It does not need to be provided in addition to the required volume.

M. **Set Aside Area.** Land area adjacent to the pond must be set aside for future disposal of sediments removed from the structure when maintenance is performed. For design purposes, the surface area required to be set aside should be computed as follows:

- Sized to accommodate at least 2% of the flood storage volume when the 2 year storm is flood routed through the pond
- Maximum depth shall not exceed 1 foot.
- Maximum slope shall not exceed 5%. The area and slope of the set aside area may be modified if an alternative area or method of disposal is approved by the appropriate plan approval agency.

For construction plans, the set aside area only needs to be delineated and labeled. The area should not be shown on the grading plans as a depressional storage area. Rather, these areas will be graded in the future at the time they are needed.

N. **Maintenance Road.** An accessway to the stormwater management pond must be provided from a public street or right-of-way and shall be not less than 10 feet wide. A curb cut must be provided.
Designers are encouraged to use the stabilized construction entrances as permanent access roadways. The stabilized construction entrance to the pond used during construction should be left in place and topsoiled, seeded, and mulched at the conclusion of the project. This will create a stabilized turf roadway for future maintenance access.

O. **Maintenance Drain.** Wet ponds created by an embankment must be equipped with a drain to facilitate maintenance. It may not be feasible to install a drain in excavated ponds. In this case, maintenance will involve pumping the pond down prior to sediment removal.

P. **Landscaping.** Landscaping for stormwater management ponds shall be designed and submitted as part of the stormwater management plan according to the following guidelines:

1) **Landscaping Buffer.** A ten foot wide buffer strip shall be provided along the perimeter of the pond beyond the top of the pond banks. The landscaping buffer should be relatively flat terrain to facilitate easy maintenance and turn around space for mowers. A landscaping plan utilizing low maintenance grasses, trees, and shrubs shall be developed for the pond and buffer area to improve aesthetics, and functionality—both hydraulic and ecological. Landscaping plans shall exclude the planting of woody vegetation, shrubs or trees on the earthen dam in embankment ponds.
The landscaping plan is an important component of the overall stormwater management plan and should be included with the project plan submittal.

2) **Pond Banks and Bottom.** The creation of a shallow marsh is encouraged in the lower stage of a dry stormwater managemement pond and wetland fringe vegetation should be planted on the submerged level bench in a wet pond to enhance sediment trapping and nutrient removal capability.

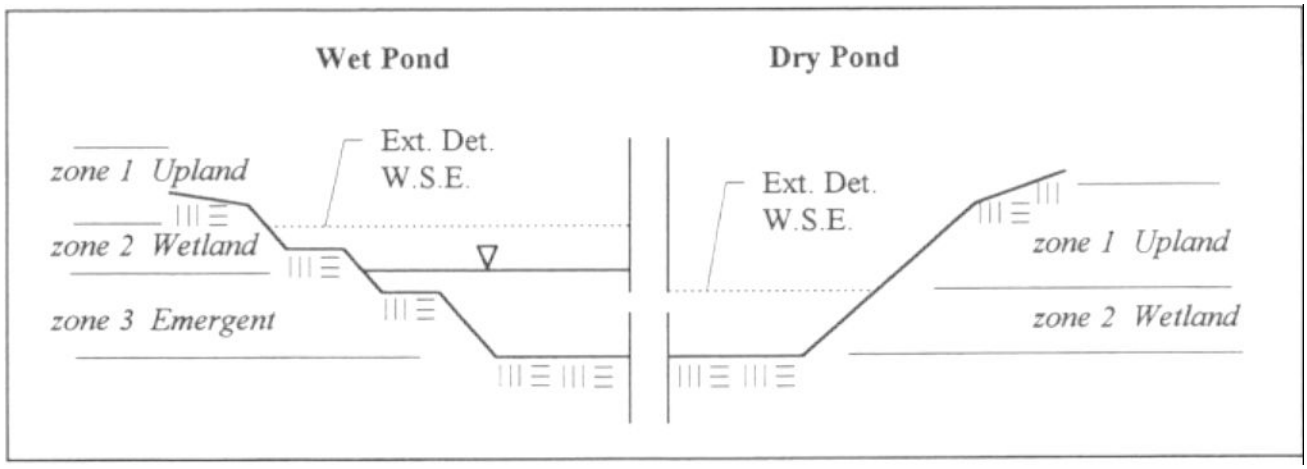


Figure 5.5 Wetland Landscaping Zones

3) **Recommended Plantings**. The following tables list the various plant material which are suitable for use in stormwater management ponds. The tables are broken down by planting zone as defined in the diagram above. Designers are encouraged to create landscaping plans utilizing a variety of grasses and woody vegetation.

Table 5.2A Recommended Plantings

Woody Shrubs
(Zone 1 - Wet and Dry Pond)

Latin Name	Common Name	Notes
Aronia melanolarpa	Black Chokeberry	
Clethra alnifolia	Sweet Pepperbush	1
Cornus foemina racemosa	Graystem dogwood	
Cornus serilea	Red-osier dogwood	
Ilex decidua	Possumhaw	
Ilex glabra	Inkberry	
Lindera benzion	Common spicebush	
Magnolia virginiana	Sweetbay magnolia	
Myrica cerifera	Wax myrtle	
Myrica pennsylvanica	Bayberry	
Rhododendron pericilymenoides	Pink azalea	1
Viburnum dentatum	Southern arrowwood	

Notes:

1) Species may also be planted in zone 1, wet ponds only. All other species listed will tolerate dry-down or drought conditions.

Table 5.2B Recommended Plantings

Woody Shrubs:
(Zone 2 - Wet and Dry Ponds)

Latin Name	Common Name	Notes
Alnus serrulata	Smooth alder	1
Aronia arbutifolia	Red chokeberry	2
Baccharis halimifolia	Groundsel Tree	
Chephalanthus occidentalis	Button bush	1
Cornus amomum	Silky dogwood	2
Ilex verticilata	Winter berry	2
Itea virginica	Virginia sweetspire	1
Leucothoe racemosa	Fetterbush	
Magnolia virginiana	Sweetbay magnolia	
Rhododendron viscosum	Swamp azalea	
Rosa palusteris	Swamp rose	

Latin Name	Common Name	Notes
Salix purpurea	Basket willow	2 NC county only
Sambucus canadensis	Elderberry	2 NC county only
Vaccinium corymbosom	Highbush blueberry	
Viburnum trilobum	American cranberry bush	2

Notes:

1) Species for use exclusively within zones 2 and 3 in wet ponds, and zone 2 in dry ponds.
2) Species may also be planted in zone 1, wet and dry ponds: Tolerates drought.

Table 5.2C Recommended Plantings

Herbaceous Emergent Vegetation:
Grass, Forbs, Sedges and Rushes
(Zones 2 and 3, Wet and Dry Ponds)

Latin Name	Common Name	Notes
Acorus calamus	Sweet flag	2
Alisma plantago - aquatica	Water plantain	1
Caltha palustris	Marsh marigold	
Carex hystricina	Porcupine sedge	
Carex lacustris	Lake sedge	1
Carex lanuginosa	Wooly sedge	2,3
Carex stricta	Tussock sedge	
Carex vulpindidea	Fox sedge	
Dulichium arundinaceum	Three-side sedge	1
Eleocharis quisetoides	Knotted spike rush	1
Eleocharis obtusa	Blunt spike rush	
Eleocharis palustris	Marsh spike rush	
Glyceria canadensis	Rattlesnake mannagrass	1,4
Glyceria grandis	Reed meadow grass	1,4
Glyceria pallida	Floating mannagrass	1,4
Glyceria septentrionalis	Mannagrass	1,4
Hibiscus moscheutas	Marsh hibiscus	
Hydrocotyle umbellata	Water pennywort	1
Iris psuedacorus	Yellow water iris	
Iris versicolor	Blue flag	
Juncus effusus	Soft rush	1
Juncus torrey	Torrey rush	3

Latin Name	Common Name	Notes
Acorus calamus	Sweet flag	2
Leersia oryzoides	Rice cutgrass	2,3
Lobelia cardinallis	Cardinal flower	
Osmunda regalis	Royal fern	
Panicum virgatum	Switchgrass	
Peltandra virginica	Arrow arum	1
Polygonum hydropiperoides	Marsh smartweed	1
Polygonum pennsylvanicum	Pennsylvania smartweed	3
Polygonum persicaria	Lady's thumb	
Polygonum punctatum	Dotted smartweed	
Pontederia cordata	Pickeral weed	1
Rumex verticillatus	Water dock	
Sagittaria graminae	Grass-like duck potato	1
Savrurus cernus	Lizard tail	1
Scirpus acutus	Hardstem, bulrush	1,2
Scirpus americanus	Olney's bulrush	3,
Scirpus cyperinus	Wool grass	2,3
Scirpus fluviatilis	River bulrush	1
Scirpus pungens	Common three square	2
Scirpus validus	Soft stem bulrush	1
Sium suave	Water parsnip	3
Sparganium americanum	Eastern bur-reed	1

Notes:

1) Species for use exclusively within zone 3, wet ponds.
2) Species which rapidly colonize distrubed areas and stabilize soil as semi-persistent or persistent plant forms.
3) Species tolerating dry down conditions such as zone 2 ,dry ponds.
4) Does not compete well with other species; should be planted as a monotypic stand, however, good species for fall planting.

5.8. Principal Spillway System

The Principal Spillway System shall be designed and sized to discharge frequent and long duration continuous flows without eroding, settling, or becoming blocked by trash and debris. For design purposes, the Principal Spillway System includes the riser assembly, the outfall pipe, outfall scour protection, all weirs, orifices, maintenance drains, trash racks, or any other appurtenance attached to the structure. All these components work together to function as one principal spillway system. Designers should note that in construction contracts payment for the various components may be made separately. See the construction specifications in Section 6 of this manual.

A. **Riser Crest Elevation.** The crest of the principal spillway riser for all stormwater management ponds shall be no less than one foot below the crest of the emergency spillway.

B. **Minimum Hydraulic Capacity.** The Principal Spillway must be sized to control the design storm events to predeveloped levels. Any combination of orifices, weirs, pipes, and risers may be employed to achieve this purpose In addition, the Principal Spillway shall meet the following minimum capacities:

Table 5.3. Minimum Spillway Capacities

Drainage Area (acre)	Effective Height of Dam[1] (ft)	Storage (acre-ft)	Minimum design storm Frequency[2]		
			Prin. Splwy. (yr)	Emer. Splwy. (yr)	Minimum duration- (hr)
20 or less	Any	Less than 50	10	100	24
More than 20	20 or less	Less than 50	10	100	24
All others			25	100	24

[1] As defined under "Scope", NRCS Pond Code 378.

[2] Select rain distribution based on climatological region.

C. **Prevention of Vortex.** Flow through a horizontal orifice, such as the top of the riser, can set up a whirlpool (called a vortex) over the top of the structure. This is a concern because a vortex can severely limit the capacity of the principal spillway riser. A vortex throttles the flow back to very low levels leaving the principal spillway flowing at less than the designed release rate. Since the water can not go through the riser, it will proceed through the emergency spillway instead with little attenuation of peak flow rates. For this reason, the principal spillway riser and barrel must be designed to prevent the formation of a vortex.

As shown in the figure below, a vortex forms at a certain headwater elevation above the top of the riser. The riser initially flows under weir flow condition but at higher energy head, the flow transitions into an orifice flow condition. Field conditions and model studies have shown that flow through the top of risers under orifice condition is unstable and causes excessive surges, vibration, noise and vortices. These conditions can reduce the flow capacity and can cause structural failure of the principal spillway system.

In order to avoid these problems, the riser must be large enough to operate under weir flow condition and to establish full pipe flow in the barrel at as low a head over the crest as practical and before orifice flow develops. This requires that the riser have a larger cross sectional area than the barrel. For a circular riser, it should be at least one standard pipe size larger than the barrel.

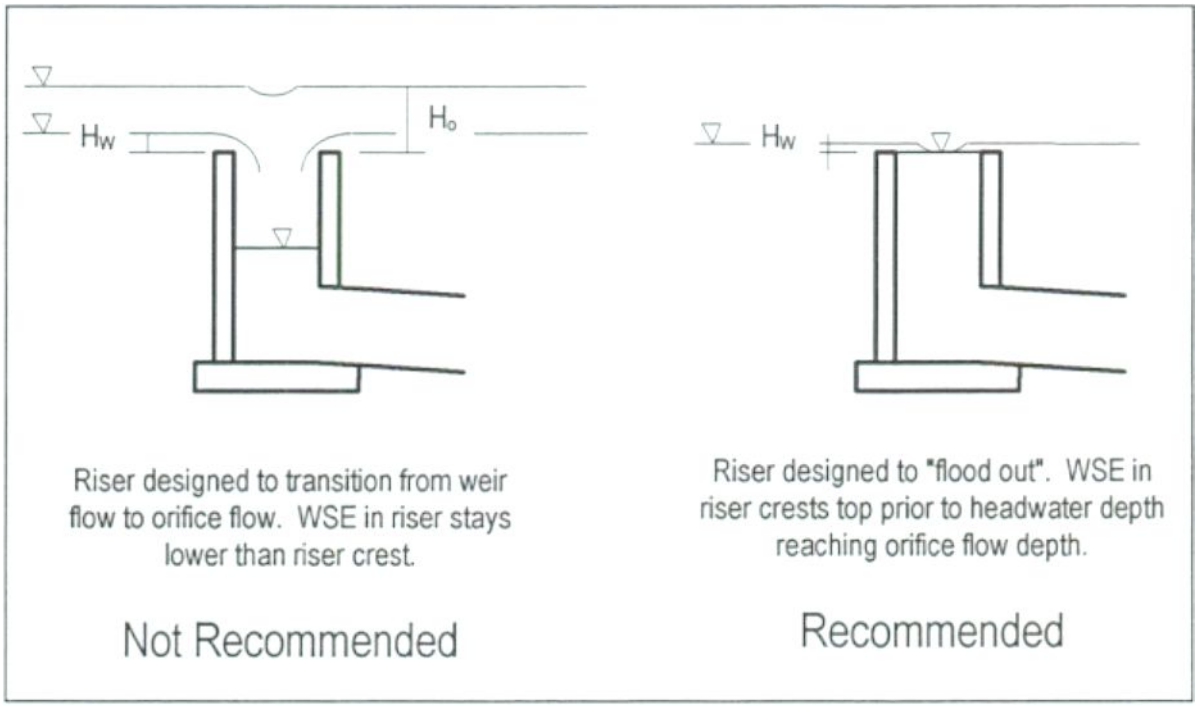
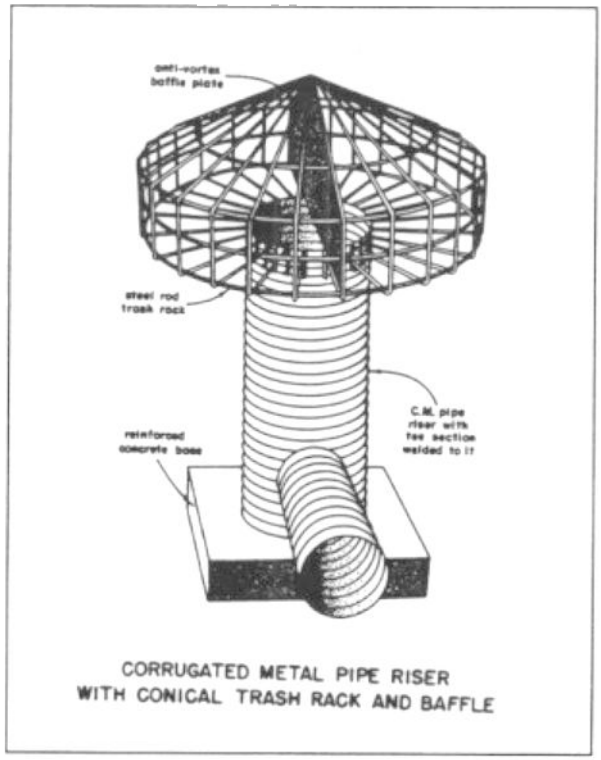


Figure 5.6. Prevention of Vortex

From a design standpoint, the problem is one of determining the elevation over the riser when the flow transitions from weir flow to orifice flow and then making sure that the barrel controls the flow at the elevation. Although it is recognized that the transition between weir and orifice control can not be accurately determined, it is usually sufficient to assume that the transition occurs where the weir equation is made equal to the orifice equation (see Hydraulic Section of this guide).



CORRUGATED METAL PIPE RISER
WITH CONICAL TRASH RACK AND BAFFLE

DelDOT does not recommend the use of vertical vane anti-vortex devices such as the one shown at left. These devices may not prevent the formation of a vortex under all flow conditions.

D. **Riser Assembly.** Pond outlet riser assemblies include the multiple stage orifices, weirs, extended detention devices, maintenance drains, and the riser structure itself. Materials used in the riser assembly should conform to following requirements:

1) **Approved Materials**
All outlet works shall be constructed of corrosion resistant materials. The following materials are approved for use in outlet structures:
   a) Reinforced concrete construction, either precast or poured in-place;
   b) High Density Polyethylene Pipe and pre-molded sections;
   c) Corrugated Aluminum Pipe and prefabricated sections;

2) **Materials Specifically Prohibited**
The following materials are specifically prohibited for use in stormwater outlet structures:
   a) Concrete block, brick, or other modular masonry units;
   b) Bituminous coatings;
   c) PVC pipe.

3) **Pond Outlet Configurations.**
DelDOT recommends the following types of pond outlet configurations:

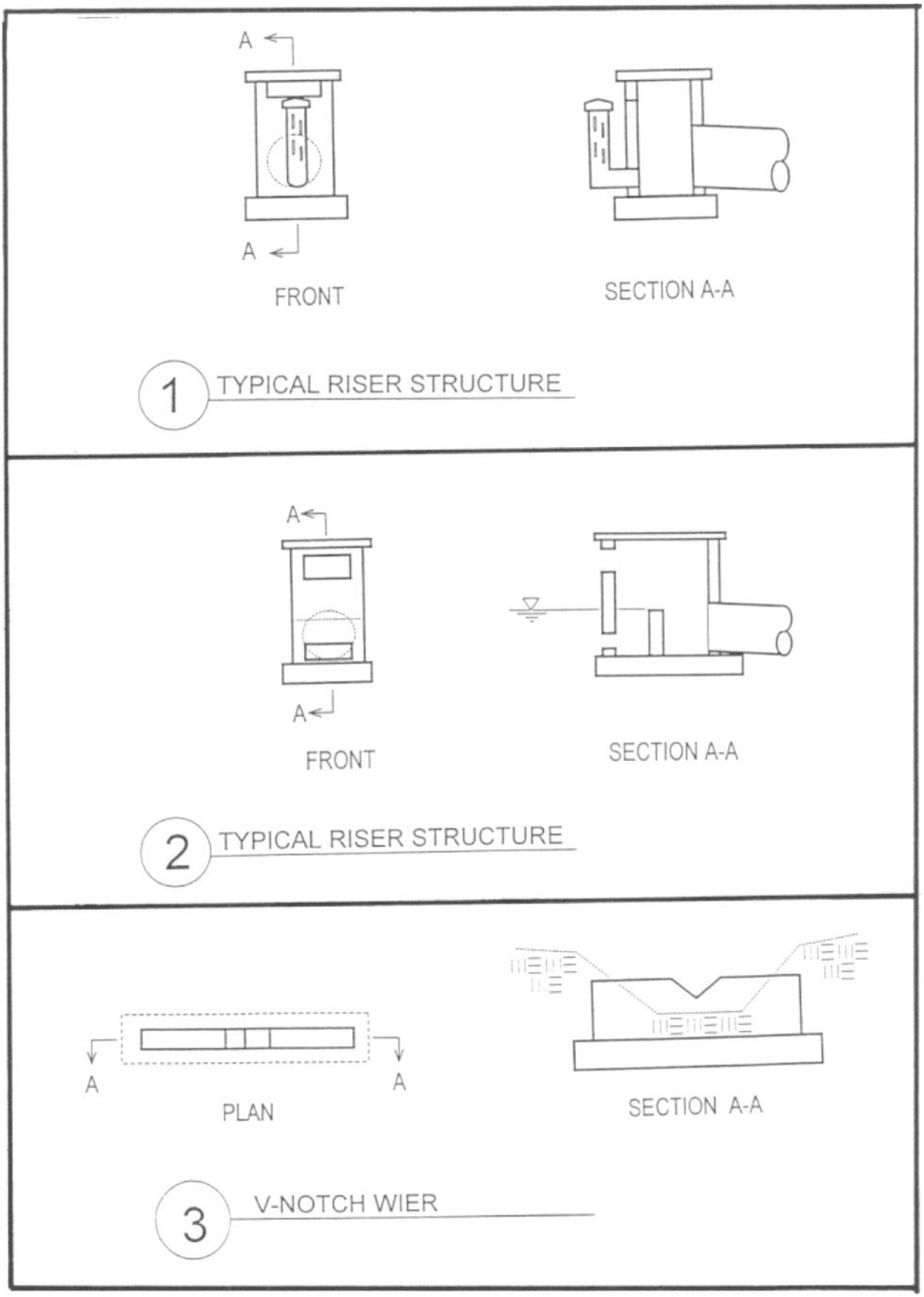


Figure 5.7. Recommended Pond Outlet Configurations

E. **Extended Detention Devices.** Extended detention devices shall be sized to provide a 24 hour release of the water quality treatment volume stipulated in Section 10.3.E.(2) & (3) of the DSSR. They shall be designed to facilitate access for maintenance and removal of sediment; and shall meet the following minimum requirements:

1) A slotted or perforated standpipe with internal orifice (See Extended Detention Detail 1) meeting the following minimum standards:
   a. 8 - inch diameter;
   b. The minimum opening of perforations in the standpipe shall be 1/2 - inch in any direction;
   c. The total cross-sectional area of the perforations in the standpipe shall be at least 5 times the cross-sectional area of the internal orifice;
   d. The standpipe shall be constructed with an internal orifice plate at least 1-1/2 inches in diameter;
   e. and a removable and lockable cap to facilitate cleanout.

2) A subsurface withdrawal must be utilized on ponds having permanent pools that discharge to thermally sensitive waters. An example of a subsurface withdrawal is an inverted pipe at least 3" in diameter placed with its inlet set at an elevation at least one foot below the normal water surface elevation. This design also works well to prevent debri clogging. See Extended Detention Detail 2.

3) One or more orifices (each at least 1.5" in diameter) equipped with a trash rack having a surface area at least 5 times the area of the smallest orifice.

4) A V-notch weir.

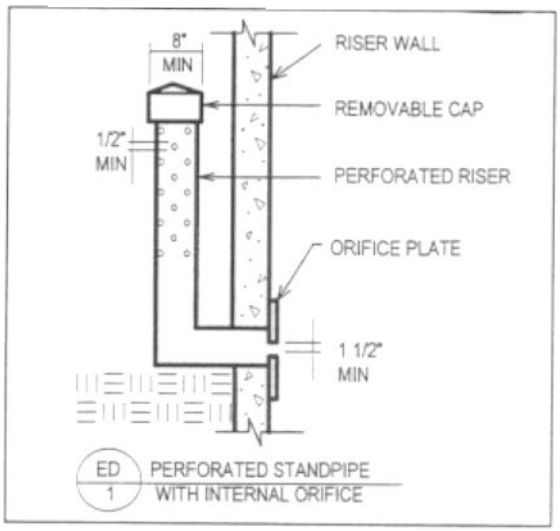


Figure 5.8. Perforated Riser

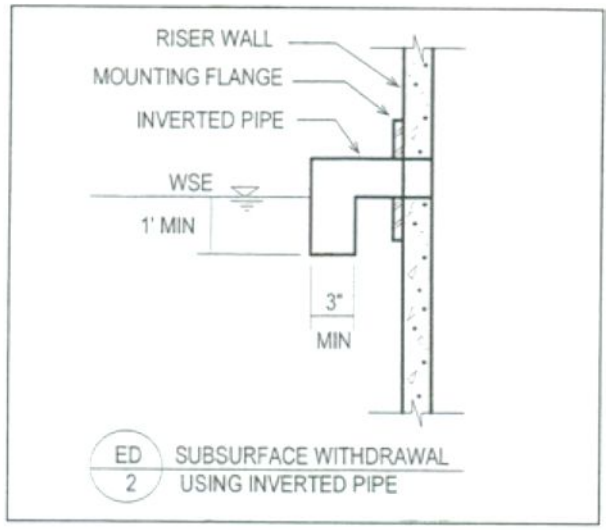


Figure 5.9. Inverted Pipe

5) Extended detention devices constructed of aluminum pipe shall meet the following minimum requirements:

Table 5.3. Minimum Gauge For Corrugated Aluminum Pipe [2-2/3-in x 1/2-in corrugations][1]

Fill height (ft)	Minimum thickness (in) of aluminum pipe[2] with diameter (in) of- 21 and less	24	30	36
1 - 15	0.06	.06	.075	.075
15-20	.06	.075	.105	.105
20-25	.06	.105	.135	[3]

[1] Pipe with 6 - , 8 - , and 10 - in. diameters has 1- 1/2 in. x 1/4 - in. corrugations.

[2] Riveted or helical fabrication.

[3] Not permitted.

F. **Principal Spillway Outfall Pipe.** All pipes projecting through earthen dams shall be reinforced concrete, class III, IV, or V. Concrete pipe bedding is required and shall be designed and installed in accordance with DelDOT Std Construction Detail for Class 'A' pipe bedding. All pipe connections shall be made watertight. Further detail on construction of the principal spillway can be found in Section 6 of this manual under the specifications for "Pond Outlet Structure".
The capacity of pond outfall pipes shall meet the requirements for principal spillways in Section 5.8.B.

G. **Anti-Seep Collars.** Anti-seep collars shall be installed around all conduits through earth embankments according to the following criteria:

* Sufficient collars shall be placed to increase the seepage length along the conduit by a minimum of 15 percent of the pipe length located within the saturation zone.
* For wet ponds, the normal saturation zone shall be determined by projecting a line at a slope of four horizontal to one vertical from the point where the normal water meets the upstream slope to a point where this line intersects the invert of the pipe conduit. For dry ponds, the normal saturation zone shall be determined from the peak water surface elevation in the pond for the storm event which generates one inch of runoff.
* Maximum collar spacing shall be 14 times the minimum projection above the pipe. The minimum collar spacing shall be 5 times the minimum projection.
* Anti-seep collars and their connections to the conduit shall be watertight and made of material compatible with the conduit.

* Collar dimensions shall extend a minimum of two feet in all direcions around the pipe.

Anti-seep collars shall be made of reinforced concrete for all DelDOT stormwater management ponds. Construction shall be as follows:

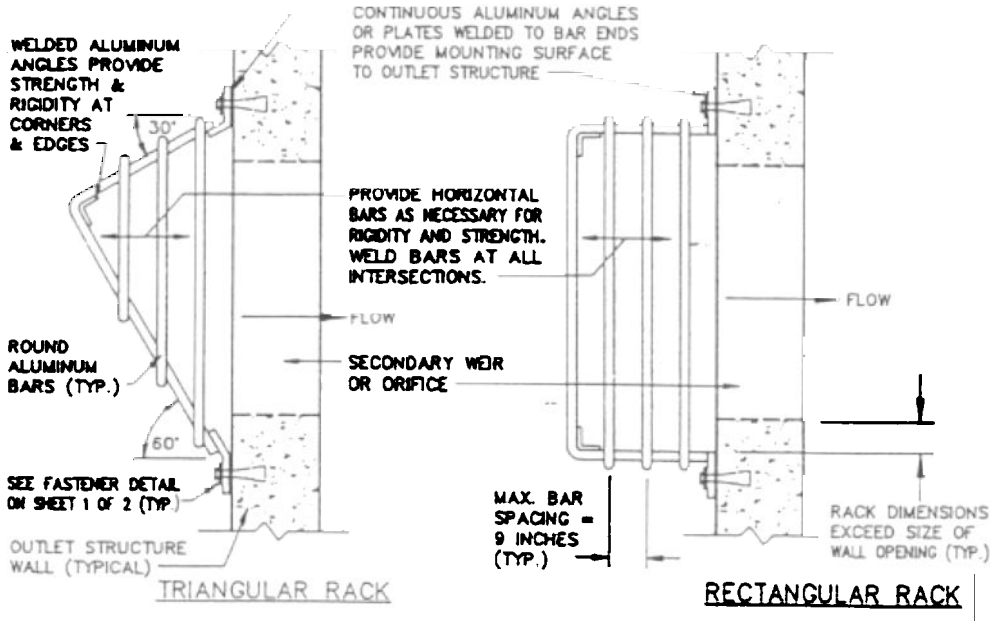
* The original ground shall be excavated to the outside dimensions of the anti-seep collar;
* The bottom half is to be cast in place using the existing ground to form the concrete;
* The top half is to be cast in place using concrete formwork.

For further discussion, see Section 6 of this manual under construction specifications for "Pond Outlet Structure".

H. **Backfill for Principal Spillway System.** Soil for backfill next to pipes and other structures built within the fill placed for an earthen dam shall be the same type and quality as the adjoining material. The backfill shall be placed in 4 inch (100 mm) horizontal layers at the same rate on all sides to prevent damage from unequal loading.

I. **Outfall Scour Protection.** The outlet of the principal spillway must be adequately protected from scour erosion. A rip rap apron, plunge pool, or other means of dissipating energy must be employed. Sizing requirements shall be in accordance with the Delaware Erosion Control Handbook or other suitable design standard such as FHWA Hydraulic Engineering Circular No. 14.

J. **Trash Racks.** Orifices shall be protected from clogging by use of trash racks. Designs should be based on the following recommended configurations:



TYPICAL CONFIGURATIONS AND DETAILS
FOR
SECONDARY WEIR OR ORIFICE TRASH RACKS

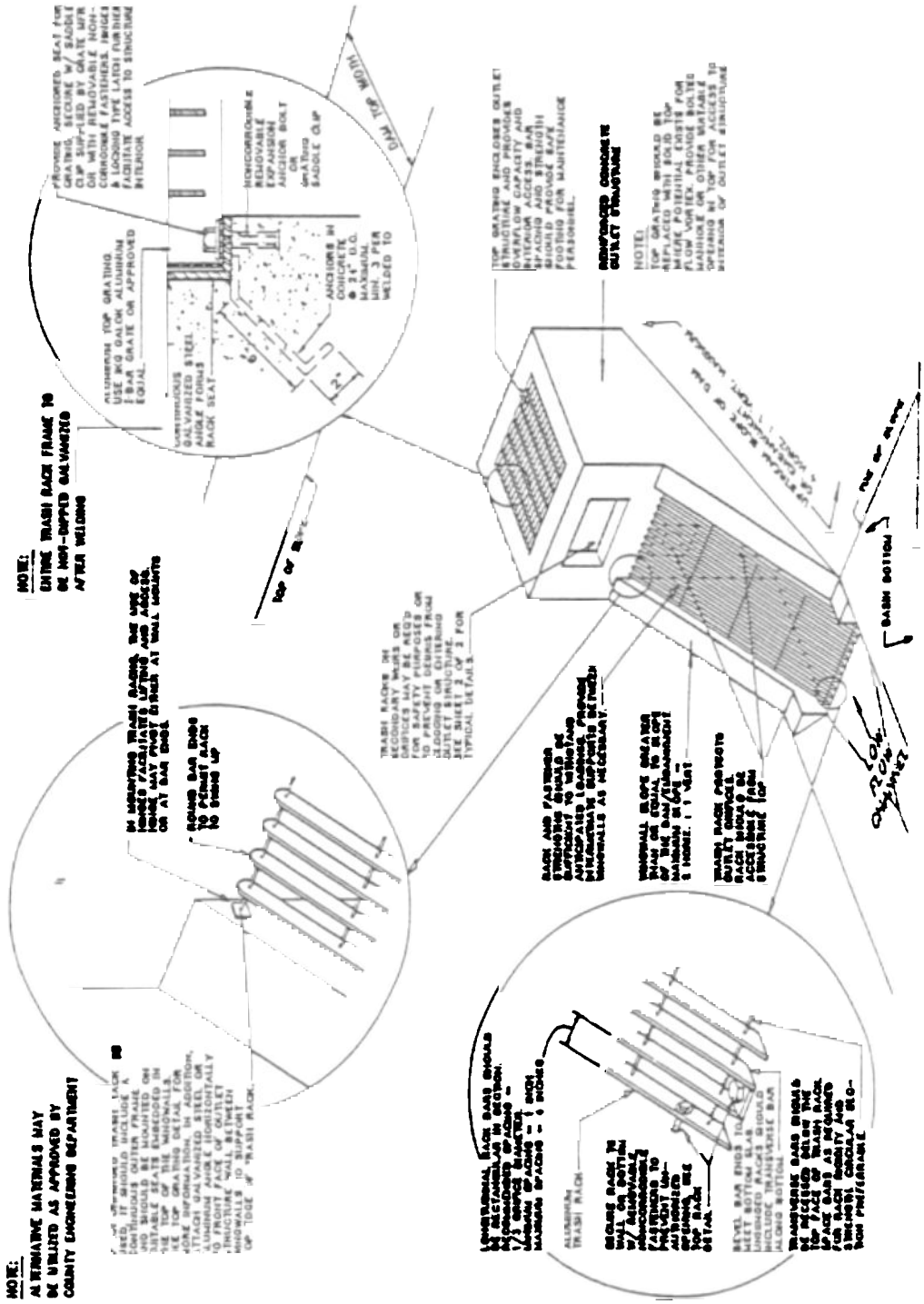


Figure 5.10. Recommended Trash Rack Configuration

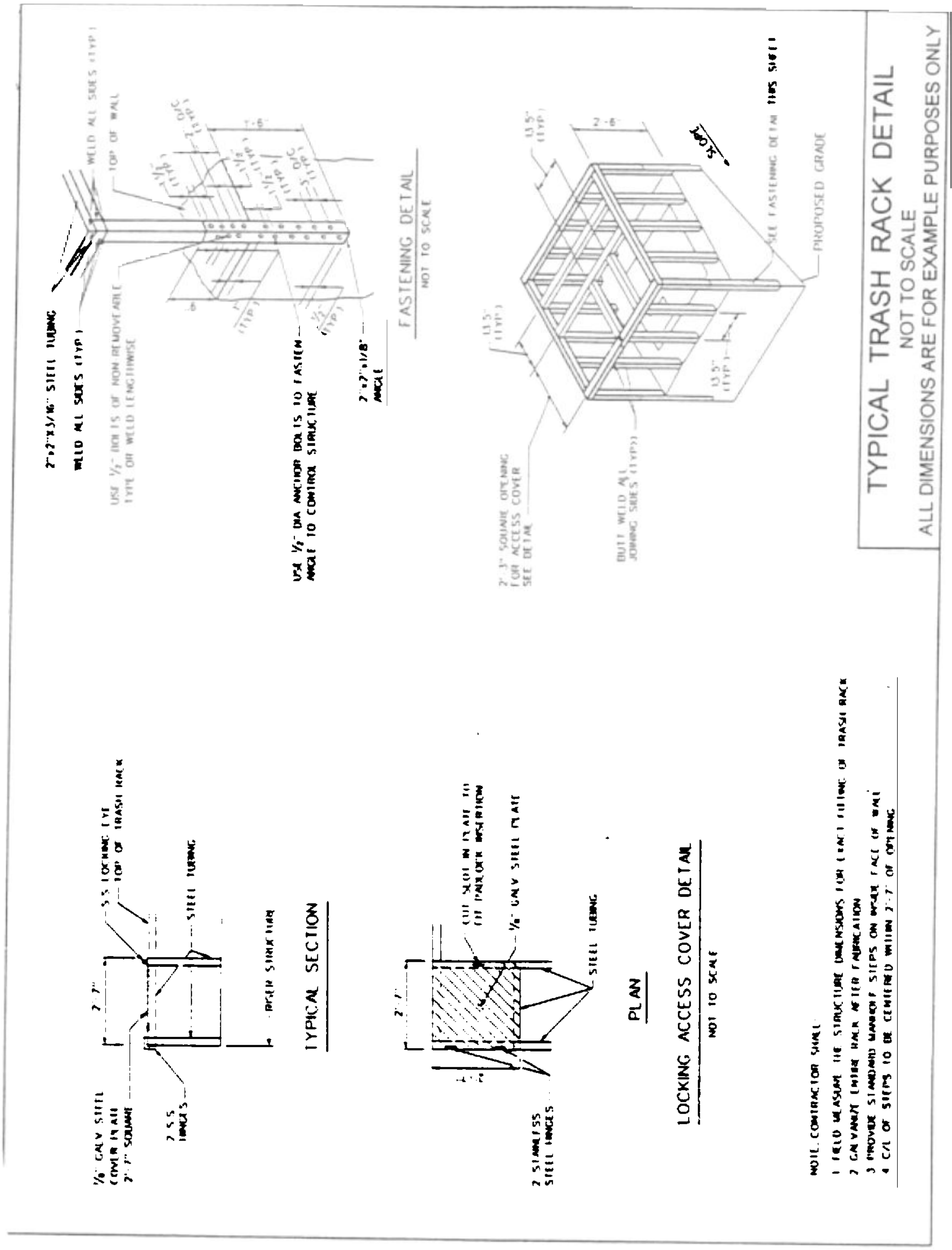


Figure 5.11. Recommended Trash Rack Configuration

5.9. Embankment Design

A. **Embankment Side Slopes.** 4 horizontal to 1 vertical side slopes are recommended on the upstream side of an embankment to facilitate mowing. The maximum allowable steepness on the upstream side slope shall be 3 horizontal to 1 vertical. The upstream side slope of the embankment must conform to the same benching requirements as the pond side slopes.

4 horizontal to 1 vertical side slopes are recommended on the downstream side of an embankment to facilitate mowing. The maximum allowable steepness on the downstream side slope shall be 2 horizontal to 1 vertical.

B. **Minimum Top Widths.** The minimum top width for an earthen dam is shown below:

Table 5.4. Minimum Embankment Top Widths

Total Height of Embankment (ft.)	Top Width (ft.)
10 or less	6
10-15	8
15-20	10
20-25	12
25-35	14
35 or more	15

If the embankment top is to be used as a State road it shall meet all DelDOT requirements regarding lane widths, superelevation rates, guardrail and other design features in accordance with the Road Design Manual.

C. **Embankment Height.** The minimum elevation of the top of the settled embankment shall be one foot above the peak water surface elevation in the pond with the emergency spillway flowing at design depth. See Subsection 5.9 for the applicable design storms for the emergency spillway.

Peak water surface elevations shall be computed considering the principal spillway 100 percent clogged. The routing shall begin with the water surface elevation at the crest of the principal spillway.

The minimum difference in elevation between the crest of the emergency spillway and the settled top of dam shall be two feet for all dams having more than a 20 acre drainage area or more than 20 feet in effective height.

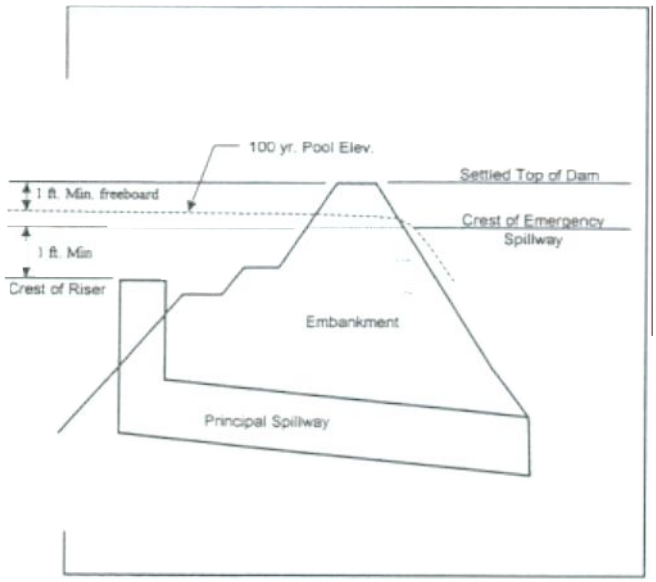


Figure 5.12. DA < 20 Acres AND Effective Height < 20 feet

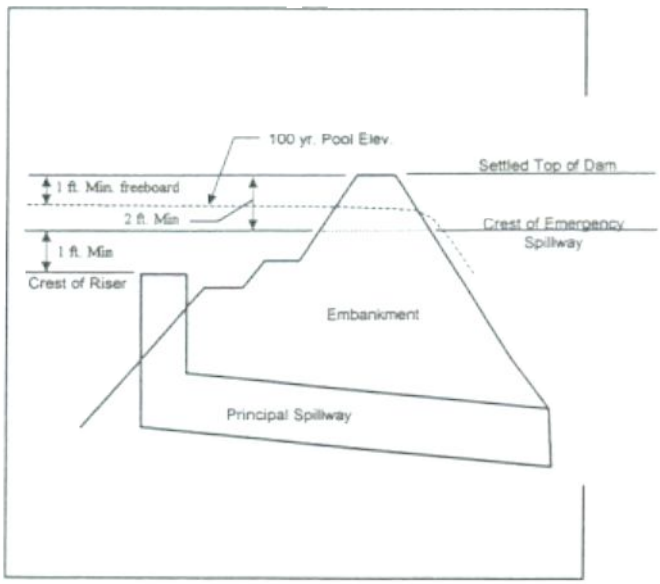


Figure 5.13. DA >20 Acres OR Effective Height > 20 Feet

D. **Embankment Settlement.** The design height of the dam shall be increased by the amount needed to ensure that after settlement the height of the dam equals or exceeds the design height. This increase shall be no less than 5 percent, except where detailed soil testing and laboratory analyses show that a lesser amount is adequate.

E. **Foundation Investigation.** Soil borings shall be taken along the dam centerline, at the dam abutments, in the emergency spillway location, and the reservoir area or planned borrow area. Soil borings shall be submitted as part of a project's stormwater management report and logged using the Unified Soil Classification System. The AASHTO Soil Classification System is not an acceptable substitute.

F. **Recommended Soil Types.** Designers should try to utilize the soil types available within the project limits. If no soil suitable for dam construction is available on the project then appropriate soils will have to be obtained from a nearby borrow source. The fill materials for foundation cutoffs and earthen dams shall meet any one of the following types under the Unified Soil Classification System:

1) **Foundation Cutoff** - SC, CL, or CH.

2) **Dam** - GC, SC, or CL

G. **Embankment Seepage Control.** In addition to anti-seep collars already discussed in Section 5.8.G., all embankment ponds must employ measures to limit seepage under the dam and along pipes projecting through the dam.

1) **Foundation Cutoff.** A foundation cutoff shall be located under the centerline of the dam or just upstream of the dam centerline. The cutoff shall be keyed into the original ground and extend down a minimum of four feet to a relatively impervious layer of soil.

A foundation cutoff is constructed by excavating a trench in the original ground and removing the pervious soils. The trench should be extended up the dam abutments to at least the peak water surface elevation during the 10 year storm event. The trench is backfilled with relatively impervious soils and compacted in 8 inch lifts. For constructability reasons, the trench generally needs to be at least four feet wide at the bottom. For safety purposes, the side slopes should be no steeper than one horizontal to one vertical. For further discussion see Section 6 of this manual under construction specifications for "Stormwater Management Pond".

2) **Control of Woody Vegetation.** No Woody vegetation, such as trees and shrubs shall be planted on the embankment. Their extensive root systems can compromise the structural integrity of an earthen dam.

5.10. Emergency Spillways

A. **Description.** Constructed emergency spillways shall be excavated in original ground (not in fill) and be trapezoidal open channels consisting of an inlet channel, a control section, and an exit channel. An emergency spillway must be provided for each dam. An embankment pond as defined in Pond Code 378 shall have an emergency spillway channel to direct large flood flows safely around earth embankments. Ponds having principal spillways designed to pass the 100 year storm events must also have an emergency spillway in the likely event that the principal spillway becomes clogged with debris.

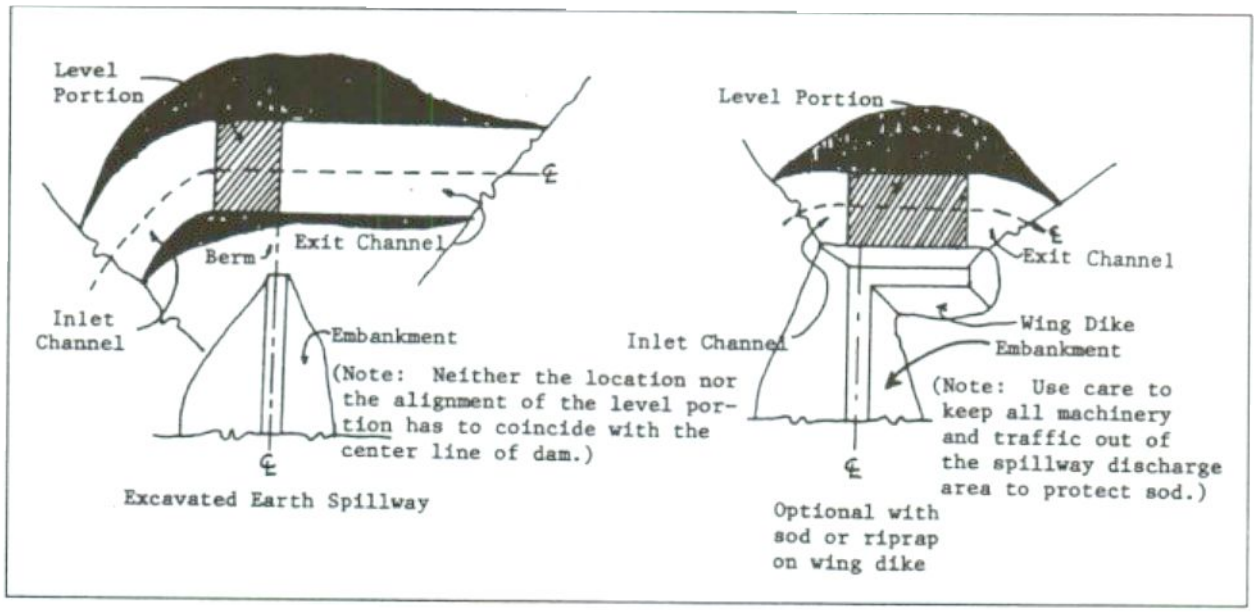


Figure 5.14. Plan View of Earth Spillways
Source: *Engineering Field Manual*, USDA - NRCS

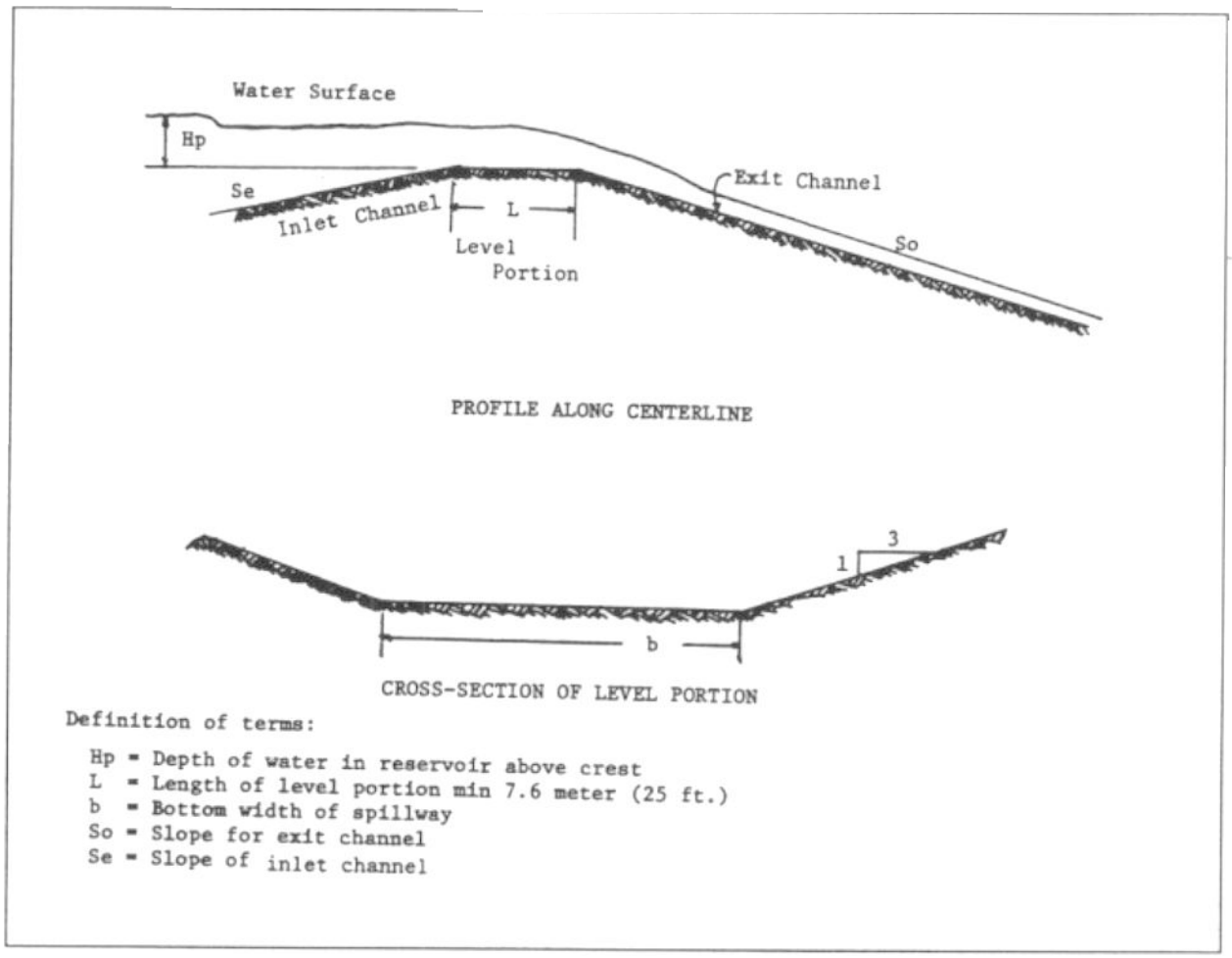


Figure 5.15. Profile and Cross Section of Excavated Earth Spillway
Source: *Engineering Field Manual*, USDA - NRCS

B. **Emergency Spillway Sizing.** Emergency spillways shall have a minimum capacity to pass the routed peak flow from the 100 year frequency, 24 hour duration design storm with at least one foot of vertical freeboard between the peak water surface elevation and the settled top of dam.
Routing of the 100 year, 24 hour duration storm event shall begin considering the principal spillway 100 percent clogged and the water surface elevation in the pond at the crest of the principal spillway riser.
All sizing procedures shall be in accordance with the NRCS Engineering Field Manual.

C. **Emergency Spillway Crest Elevations.** The crest elevation of the emergency spillway shall be set at least one foot above the crest of the principal spillway. For dams having more than a 20 acre drainage area or more than 20 feet in effective height, the emergency spillway crest shall be set at least 2 feet lower than the settled top of dam.

D. **Side Slopes.** Side slopes of the emergency spillway shall be no steeper than one vertical to three horizontal.

E. **Minimum Width.** For dams having an effective height exceeding 20 feet, the emergency spillway shall have a bottom width of not less than 10 feet.

F. **Scour Protection.** Emergency spillways shall provide for passing the design flow through the exit channel at a safe velocity to a point downstream where the dam will not be endangered by scour.

G. **Overflow Spillway.** Excavated ponds must have an overflow spillway having a minimum capacity to safely direct the design storm event to receiving waters with at least six inches of vertical freeboard between the peak water surface elevation and the nearest structure, or roadway downstream of the pond. The design storm for an overflow spillway in an excavated pond shall be the 10 year, 24 hour duration storm event.

5.11. Lands & Activities Regulated By Other Agencies

A. **Construction in wetlands.** The State of Delaware does not encourage the use of existing wetlands for stormwater management purposes. When no other reasonable alternative exists, it may be possible to incorporate wetlands as a component of an overall stormwater management system if the following criteria are adhered to:

1) The only disturbance to the wetland shall be that disturbance caused by the stormwater management pond embankment placement or construction; or

2) It can be demonstrated that the intended or functional aspects of the stormwater management facility and wetlands are maintained or enhanced;

3) All other necessary state and federal permits have been obtained and evidence of this is included with the plan submission.

B. **Design Requirements for Sedimentation Control and Stormwater Management.** In the event of a conflicting law, ordinance, regulation, or policy from one or more federal, state, or local agency, the most stringent requirement shall govern.

Hazard Classification Form

Project Name: _____

_____

Contract No.: _____

Coordinates at approximate centerline of Dam:

N _____ E _____

Name of Receiving Stream _____

Name of Watershed _____

Hazard Description:

_____

_____

_____

_____

_____

Hazard Classification: _____ ("a", "b", or "c")

Certification:
I hereby certify to the best of my knowledge and belief that the above hazard description is true and accurate and the classification for this dam is made in accordance with Pond Code 378 as required under the Delaware Sediment and Stormwater Regulations.

_____ _____

Name Date

This form valid only when signed, dated, and sealed by a Professional Engineer registered in the State of Delaware.